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Electrocardiography and prognosis of patients with acute pulmonary embolism

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Abstract

Background: *To assess the influence of electrocardiographic (ECG) pattern on prognosis and complications of patients hospitalized with acute pulmonary embolism (APE).*

Methods: *We performed a retrospective analysis of 292 patients who had confirmed APE. There were 183 females and 109 males, the age range was 17 to 89 years, and the mean age was 65.4 ± 15.5 years.*

Results: *In our study group, there were 33 deaths (mortality rate, 11.3%), and 73 (25%) patients developed complications during hospitalization. Based on European Society of Cardiology risk stratification, we classified 75 (25.7%) patients as high risk, 163 (55.8%) patients as intermediate risk, and 54 (18.5%) patients as low risk. A comparison between patients with complicated APE and those with no complications during hospitalization indicated that the following ECG parameters were more common in patients who had complications: atrial fibrillation, S1Q3T3 sign, negative T waves in leads V2–V4, ST segment depression in leads V4–V6, ST segment elevation in leads III, V1 and aVR, qR in lead V1, complete right bundle branch block (RBBB), greater number of leads with negative T waves, and greater sum of the amplitude of negative T waves. In multivariate analysis, the sum of negative T waves (OR 0.88; p = 0.22), number of leads with negative T waves (OR 1.46; p = 0.001), RBBB (OR 2.87; p = 0.02) and ST segment elevation in leads V1 (OR 3.99; p = 0.00017) and aVR (OR 2.49; p = 0.011) were independent predictors of complications during hospitalization. In turn, in multivariate analysis, only the sum of negative T waves (OR 0.81; p = 0.0098), number of leads with negative T waves [OR 1.68; p = 0.00068] and ST segment elevation in lead V1 (OR 4.47; p = 0.0003) were independent predictors of death during hospitalization.*

Conclusions: *In our population of APE patients, the sum of negative T waves, the number of leads with negative T waves and the ST segment elevation in lead V1 were independent predictors of death during hospitalization. In turn, the sum of negative T waves, the number of leads with negative T waves, and RBBB and ST segment elevation in leads V1 and aVR were independent predictors of complications during hospitalization. We conclude that ECG analysis may be a useful noninvasive method for risk stratification of patients with APE.* (Cardiol J 2011; 18, 6: 648–653)

Key words: acute pulmonary embolism, electrocardiogram, mortality, complications

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Introduction

Acute pulmonary embolism (APE) is a major cause of cardiovascular mortality. Despite progress in the diagnosis and treatment of APE, the mortality rate can reach 15% for high-risk patients [1]. Spiral computed tomography (CT) is the most widely used and preferred method for the diagnosis of APE [1]. Electrocardiography (ECG) typically has poor sensitivity and specificity in the diagnosis of APE. However, if ECG, which can be performed in the emergency room during initial medical contact, can be used to diagnose APE, it would allow for the early initiation of therapy and an improved prognosis for patients with APE.

The ECG of patients with APE can present as normal, or with rhythm disturbances (supraventricular, ventricular), conduction disturbances (right bundle branch block [RBBB]), changes in axis deviation (right or left axis deviation), changes in P wave morphology (P pulmonale), changes in QRS complex (low QRS voltage), repolarization abnormalities (negative T wave, ST depression or ST elevation), or QT prolongation [2].

The purpose of the present study was to assess the frequency of different ECG patterns in patients diagnosed with APE and to assess the influence of ECG pattern on prognosis and complications during the hospitalization of these patients.

The study was performed as part of the regional 'Malopolska Acute Pulmonary Registry' [3].

Methods

We performed a retrospective analysis of 292 patients who experienced APE (183 females, 109 males, age range: 17 to 89 years, mean age: 65.4 ± 15.5 years). The mean hospitalization time was 15 days (range: 1–46 days). Table 1 shows the baseline clinical and demographic characteristics of all patients.

APE was diagnosed based on (1) spiral CT: 252 (86.3%) patients; (2) echocardiography: 24 (8.2%) including right ventricular overload: 16 patients, thrombus: eight patients; (3) ultrasound lower limb Doppler: nine (3.0%) patients; (4) scintigraphy: five (1.7%) patients; or (6) autopsy: two (0.7%) patients.

Electrocardiographic analysis

For all patients, standard 12-lead ECG was recorded on admission with a paper speed of 25 mm/s. The first available ECG was used for analysis. The following ECG parameters were analyzed:

Table 1. Demographic and clinical characteristics of enrolled patients.

Characteristic	Value
Age [years]	65.4 ± 15.5
Female:male	183:109 (62.7%:37.3%)
Stenocardia	128 (43.8%)
Syncope	87 (29.8%)
Obesity	92 (31.5%)
Immobilization	85 (29.1%)
Thrombophlebitis	136 (46.6%)
Hemoptysis	10 (3.4%)
Neoplastic disease	22 (7.5%)
Oral contraception	8 (2.7%)
Congestive heart failure NYHA class III/IV	36 (12.3%)
Chronic obstructive pulmonary disease	24 (8.2%)
Pre-febrile status under diagnosis	36 (12.2%)
Duration of hospitalization [days]	15.08

- supraventricular or ventricular arrhythmia;
- QRS axis deviation;
- P-pulmonale; amplitude of P wave greater than 0.25 mV in at least one limb lead (II, III, and aVF); RBBB;
- McGinnWhite sign (S1Q3T3 complex);
- negative T wave in leads III and aVF;
- negative T waves in leads V2–V4; T segment depression in leads V4–V6;
- ST segment elevation in leads aVR, III, V1 and V2–V4;
- fragmentation in R wave or S wave in leads aVR and V1;
- amplitude of S wave and sum of the amplitude of S waves in leads V4 and V5;
- (q)R complex in lead V1;
- clockwise rotation; ratio of amplitude of R wave to S wave ≤ 1 in lead V5;
- low QRS voltage (< 5 mm) in the limb leads;
- sum of the amplitude of negative T waves in the limb leads and in the precordial leads;
- and number of leads with negative T waves.

The following clinical event complications were recorded: death from all causes, cardiac arrest, treatment with catecholamines, cardiogenic shock on admission or during hospitalization, and respiratory support by mechanical ventilation.

The frequency of ECG change associations with clinical complications was analyzed.

Table 2. Electrocardiographic changes in subgroups of patients with acute pulmonary embolism who survived, died, with or without complications during in-hospital stay.

ECG parameters	All patients	Death (n = 33)	Survival (n = 259)	P	Complicated APE (n = 73)	APE without complications (n = 219)	P
Atrial fibrillation	62 (21.2%)	11 (33.3%)	51 (19.7%)	0.07	23 (31.5%)	39 (18.1%)	0.01
Left axis deviation	139 (47.6%)	15 (45.4%)	124 (47.9%)	NS	31 (42.4%)	110 (50.2%)	NS
Right axis deviation	48 (16.4%)	8 (24.2%)	40 (15.4%)	NS	16 (21.9%)	32 (14.6%)	NS
S1Q3T3 sign	92 (31.5%)	19 (57.6%)	73 (28.1%)	0.006	37 (50.7%)	38 (17.3%)	0.000
Negative T wave in leads V2–V4	120 (41.0%)	19 (57.6%)	101 (38.9%)	0.04	42 (57.5%)	76 (34.7%)	0.0005
Sum of amplitude of negative T waves	5.2	5.9	5.1	NS	6.3	4.9	0.04
Amount of leads with negative T wave	3.0	4.2	2.8	0.006	3.9	2.7	0.003
ST depression in leads V4–V6	77 (26.4%)	15 (45.5%)	62 (23.9%)	0.01	29 (39.7%)	48 (21.9%)	0.003
ST elevation in III	39 (13.3%)	10 (30.3%)	29 (11.1%)	0.003	17 (23.3%)	22 (10.0%)	0.000
Right bundle branch block	35 (11.9%)	9 (27.3%)	26 (10.0%)	0.004	16 (21.9%)	19 (8.7%)	0.002
qR in V1	33 (11.3%)	10 (30.3%)	23 (8.9%)	0.0002	15 (20.5%)	18 (8.2%)	0.004
ST elevation in V1	72 (24.6%)	20 (60.6%)	52 (20.0%)	0.0001	38 (52.0%)	36 (16.4%)	0.000
ST elevation in aVR	126 (43.1%)	22 (66.6%)	104 (40.1%)	0.004	51 (69.9%)	78 (35.6%)	0.000
Clockwise rotation	178 (60.9%)	23 (69.7%)	155 (59.9%)	NS	44 (60.3%)	134 (61.2%)	NS
P-pulmonale	44 (15.0%)	5 (15.1%)	39 (15.0%)	NS	10 (13.7%)	34 (15.5%)	NS
Low QRS voltage	23 (7.9%)	4 (12.1%)	19 (7.3%)	NS	9 (12.3%)	14 (6.4%)	NS

Statistical analysis

Categorical variables were expressed as numbers or percentages, and continuous variables as medians ± standard deviation. For comparison of categorical variables, a χ^2 test with Yates' correction was used. The Mann-Whitney test was used to compare numerical variables. All ECG variables were entered into logistic regression analysis to identify independent predictors of in-hospital complications and mortality. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. A two-tailed p value of less than 0.05 was considered statistically significant. All statistical analysis was performed using Statistica PL (StatSoft 8.0, StatSoft Polska, Krakow, Poland).

Results

In our 292 APE patients, there were 33 deaths, corresponding to a mortality rate of 11.3%. A total of 73 (25%) patients had complications during hospitalization. Based on European Society of Cardiology (ESC) risk stratification, there were 75 (25.7%) high-risk patients, 163 (55.8%) intermediate-risk patients, and 54 (18.5%) low-risk patients.

The ECG patterns in our entire study group, in patients who died during hospitalization and survived, are shown in Table 2. In the 33 patients who died during hospitalization (Table 2), the following ECG variables were significantly more common: McGinn-White sign (S1Q3T3); negative T waves in leads V2–V4; ST segment depression in leads V4––V6; ST segment elevation in leads III, V1 and aVR; Kucher's sign (qR, QR in lead V1); complete RBBB; and more leads with negative T waves.

In univariate regression analysis, predictors of death were: S1Q3T3 sign, number of leads with negative T waves, ST depression in leads V4–V6, ST elevation in lead III, V1 and aVR, RBBB and QR sign (Table 3). In turn, in multivariate analysis, only the sum of negative T waves, number of leads with negative T waves and ST segment elevation in lead V1 were independent predictors of death during hospitalization (Table 4).

During hospitalization, 73 (25%) patients experienced complications. In patients with complicated APE, the following were more common: atrial fibrillation; McGinn-White (S1Q3T3) sign; negative T waves in leads V2–V4; ST segment depression in leads V4–V6; ST segment elevation in leads III, V1, and aVR; Kucher's sign (qR, QR in lead V1); complete RBBB; more leads with negative T waves; and greater sum of the amplitude of negative T waves (Table 2).

Table 3. Univariate regression analysis in prediction of death and complications during in-hospital stay.

ECG parameter	In-hospital death			In-hospital complications		
	OR	CI	P	OR	CI	P
Atrial fibrillation	0.98	0.89–1.09	0.82	0.98	0.911–1.06	0.69
S1Q3T3	3.39	1.61–7.14	0.001	2.99	1.72–5.19	0.0001
Negative T wave III, aVF	1.95	0.91–4.14	0.08	1.51	0.88–2.6	0.12
Negative T wave V2–V4	1.58	1.90–2.77	0.11	1.88	1.15–3.08	0.01
Sum of negative T waves	1.02	0.96–1.08	0.45	1.045	0.998–1.09	0.058
Number of leads with T waves	1.21	1.05–1.38	0.005	1.21	1.09–1.34	0.003
ST depression V4–V6	2.60	1.23–5.49	0.01	2.45	1.38–4.34	0.002
ST elevation III	3.41	1.47–7.92	0.004	2.82	1.39–5.66	0.004
Right bundle branch block	3.43	1.43–8.22	0.0058	3.00	1.44–6.24	0.003
QR V1	4.42	1.87–10.46	0.0007	2.99	1.41–6.33	0.004
ST elevation V1	5.69	2.65–12.22	0.0001	5.76	3.19–10.39	0.000001
ST elevation aVR	2.78	1.29–6.00	0.009	4.58	2.54–8.25	0.000006
Dextrogyria	1.52	0.69–3.35	0.28	0.95	0.55–1.64	0.85
P pulmonale	0.97	0.32–2.91	0.97	0.90	0.41–1.96	0.79
Low QRS voltage	1.70	0.54–5.38	0.36	2.00	0.87–4.87	0.12

Table 4. Independent prognostic ECG parameters of in-hospital death in multivariate model analysis.

ECG parameters	OR	95% CI	P
Sum of negative T waves	0.81	0.69–0.95	0.0098
Number of leads with negative T waves	1.68	1.68–2.26	0.00068
ST elevation in V1	4.47	1.99–9.99	0.0003

Table 5. Independent prognostic ECG parameters of in-hospital complications in multivariate model analysis.

ECG parameters	OR	95% CI	P
Sum of negative T waves	0.88	0.78–0.98	0.022
Number of leads with negative T waves	1.46	1.16–1.85	0.001
Atrial fibrillation	0.95	0.85–1.05	0.3
Right bundle branch block	2.87	1.15–7.19	0.02
ST elevation in V1	3.99	1.96–8.18	0.00017
ST elevation in aVR	2.49	0.799–0.993	0.011

In univariate regression analysis, predictors of complicated in-hospital stay were: S1Q3T3 sign, negative T waves in leads V2–V4, number of leads with negative T waves, ST depression in leads V4––V6, ST elevation in lead III, V1 and aVR, RBBB and QR sign (Table 3). In turn, in multivariate analysis, the sum of negative T waves, number of leads with negative T waves, RBBB and ST segment elevation in leads V1 and aVR were independent predictors of complications during hospitalization (Table 5).

Discussion

The main clinical symptoms of APE are dyspnea and chest pain, but patients with APE can present with a wide spectrum of additional symptoms, thereby complicating diagnosis. ECG is one of the first diagnostic methods used for patients who present with symptoms suggestive of APE, but no specific ECG results indicative of APE. In general, ECG is regarded as a helpful tool in the differential

diagnosis of acute cardiac disease. According to current ESC guidelines, patients with APE can be classified by their risk of death [1]. ECG measurements are not considered in the ESC risk stratification.

However, several previous studies have suggested that ECG may be useful for APE risk stratification. For example, Toosi et al. [4] proposed a 21-point system based on ECG measurements, and demonstrated that an ECG score greater than, or equal to, 3 predicted right ventricular (RV) dysfunction with sensitivity, specificity, and positive and negative predictive values of 76%, 82%, 76%, and 86%, respectively. In addition, they demonstrated that an ECG score greater than, or equal to, 3 predicted a complicated disease course and mortality incidence with sensitivities of 58% and 59%, specificities of 60% and 58%, positive predictive values of 16% and 10%, and negative predictive values of 89% and 95%, respectively [4]. Punkollu et al. [5] reported that ECG could be useful in predicting RV dysfunction. In their study of 81 patients with APE, patients with RV dysfunction were more likely to have McGinn-White sign (sign S1Q3T3) and negative T waves in leads V1–V3. These authors also used an ECG-based point system to predict perfusion defect. Iles et al. [6] used a point system to predict perfusion defect, and reported a sensitivity of 70% and specificity of 59%. Kostrubiec et al. [7] used a 21-point ECG score to predict RV dysfunction, and reported a sensitivity of 92% and a negative predictive value of 97%; similarly, complications during hospitalization were predicted with sensitivity and negative predictive value of 75% and 92%, respectively).

In the present study, we showed that analysis of the first ECG following hospital admission can help in risk stratification of patients with APE. In the group of our patients who died during their hospital stays, the first recorded ECG was more likely to have McGinn-White sign (S1Q3T3), negative T waves in leads V2–V4, ST segment depression in leads V4–V6, ST segment elevation in leads III, V1, V2 and aVR, Kucher's sign (qR, QR complex in lead V1), RBBB, and more leads with negative T waves.

Kucher et al. [8] studied a group of 75 patients with APE and confirmed the prognostic significance of QR (qR) sign in lead V1. They also reported that the QR(qR) sign was present in 19% of APE patients, and 60% of patients with QR signs died during hospitalization. We found this was present in 11% of our APE patients and was a predictor of complicated APE in univariate analysis.

In our analysis of patients with complicated APE, the following ECG results were significantly more common: atrial fibrillation, McGinn-White sign (S1Q3T3), negative T waves in leads V2–V4, ST segment depression in leads V4–V6, ST segment elevation in leads III, V1 and aVR, Kucher's sign (qR, QR in lead V1), RBBB, more leads with negative T waves, and greater sum of the amplitude of negative T waves.

The study by Geibel et al. [9], which examined 508 APE patients, and our present study, which examined 292 APE patients, are the largest studies of ECG changes in patients with APE. Geibel et al. [9] showed that abnormal ECG was an independent predictor of 30-day mortality (hazard ratio [HR] 2.56). The following ECG variables were taken as abnormal: complete RBBB, atrial arrhythmias, ST segment depression in leads V4–V6, and ST segment elevation in lead I, aVL and V4–V6, Q waves in lead III and aVF, low QRS voltage in the limb leads [9].

Our study showed that in APE patients, the sum of negative T waves, number of leads with negative T waves and ST segment elevation in lead V1 were independent predictors of death during hospitalization.

Vanni et al. [10] showed that right ventricular strain pattern on ECG (RBBB, S1Q3T3, negative T waves in leads V1–V4) is associated with short-term poor prognosis (HR 2.58) independently on echocardiographic findings in patients with APE and normal blood pressure. In the study by Escobar et al. [11] of hemodynamically stable patients with acute symptomatic APE, the presence of sinus tachycardia and atrial arrhythmia were independent predictors of a poor prognosis.

In turn, in our study, the independent ECG predictors of complications during hospitalization were the sum of negative T waves, number of leads with negative T waves, RBBB and ST segment elevation in leads V1 and aVR. Kosuge et al. [12] showed similarly to our study that on multivariate analysis the hypotension and inverted T waves in ≥ 7 leads on the admission ECG (OR 16.8) were the only independent predictors of in-hospital complicated events.

Kostrubiec et al. [13] found out that troponin T level correlated with the number of leads with negative T waves and ST segment depression. Additionally, they showed that negative T waves or ST segment depression were more frequently observed in patients with an elevated level of troponin T.

We suggest that future studies should consider the prognostic significance of negative T waves in patients with APE. We found that the presence

of negative T waves in leads V2–V4 was associated with poor prognosis, but the number of leads with negative T waves and the sum of the amplitudes of negative T waves were independent predictors of complications and death during the hospital stays of patients with APE.

Limitations of the study

Our study did not address either the sensitivity or specificity of the individual criteria, since all patients in this study had APE, while no patients without APE were included. Actual predictive value for APE, as distinct from APE death and complications within an APE group, would require a comparable group of sick patients without APE and perhaps with similar symptoms.

Conclusions

In our population of APE patients, the sum of negative T waves, number of leads with negative T waves and ST segment elevation in lead V1 were independent predictors of death during hospitalization. In turn, the sum of negative T waves, number of leads with negative T waves, RBBB and ST segment elevation in leads V1 and aVR were independent predictors of complications during hospitalization.

We conclude that ECG analysis may be a useful noninvasive method for risk stratification of patients with APE.

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